COST AND PERFORMANCE REPORT

Phytoremediation at the Open Burn and Open Detonating Area
Ensign-Bickford Company
Simsbury, Connecticut

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U.S. Environmental Protection Agency
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Technology Innovation Office

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Background Information

During 1996 – 1997, Edenspace Systems Corp. (formerly known as Phytotech, Inc.) conducted a full-scale phytoremediation project for The Ensign-Bickford Company, Simsbury, Connecticut, in order to reduce total lead concentrations in a 1.5-acre area surrounding the OB/OD Area. The initial success warranted ongoing and expanded treatment in 1998 to include a total of 2.35 acres and to address not only reductions in total lead concentrations, but also address stabilizing leachable lead in the soil. This case study describes the phytoremediation processes used and results obtained during 1998. Further treatment is planned during 1999 and 2000.

The OB/OD Area is located within the 100-year flood plain of the Farmington River. The water table in the area is shallow, seasonally ranging in depth from 2 to 4 feet below the surface soil. Substantial portions of the area are poorly drained and remain extremely wet or saturated throughout the growing season (Phytotech, Inc., 1999). The characteristics of the climate and soil matrix are summarized in Table 1.

Table 1. General Characteristics of the Climate and Soil Matrix Around the OB/OD Area

Parameter	Value
Climate	Humid; growing season from April – October
Depth to water table	0 – 4 feet
Soil type	Silt loam
pH	6.5 – 7.5

Source: Phytotech, Inc., 1999; Blaylok, 1999b.

Baseline soil investigations conducted in 1990 – 1992 identified lead in soils in the vicinity of the OB/OD Area at concentrations above levels acceptable to the client. The characterization also showed that the levels of lead were not uniformly distributed. Phytoremediation activities designed to reduce total soil lead concentrations were initiated at the site in 1996 and 1997. As a result of these activities, the average soil lead concentration in the top 6 inches of soil decreased by approximately 150 mg/kg. However, much of the treated area still remained above 1000 mg/kg with some areas exceeding 2000 mg/kg and a few samples exceeding 4000 mg/kg. In addition, soil data showed leachable lead concentrations exceeding 0.015 mg/L using the Synthetic Precipitation Leaching Procedure (SPLP).

Because of the wide range of lead concentrations, the 1998 treatment approach was to combine phytoextraction (for treatment of high concentrations) with phytostabilization (for treatment of low concentrations) in order to reduce both total soil lead concentrations and SPLP extractable lead. During 1998, the treatment areas consisted of phytoremediation of 2.35 acres of level ground surrounding the OB/OD Area and the area south and west of a testing area (Figure 1). At the start of the growing season (April 1998), a soil survey was conducted using a portable XRF spectrophotometer to measure total lead concentrations, and samples were collected for laboratory leachability analyses by SPLP (EPA Method 1312). Analysis results showed that surface soil lead concentrations ranged from less than 100 mg/kg to greater than 2000 mg/kg, with an average of 635 mg/kg.

The total treatment area (2.35 acres) was segregated into five treatment areas based on the initial soil survey (Figure 1). Areas 1 through 4 (approximately 17% of the total treatment area, or 0.4 acre) had

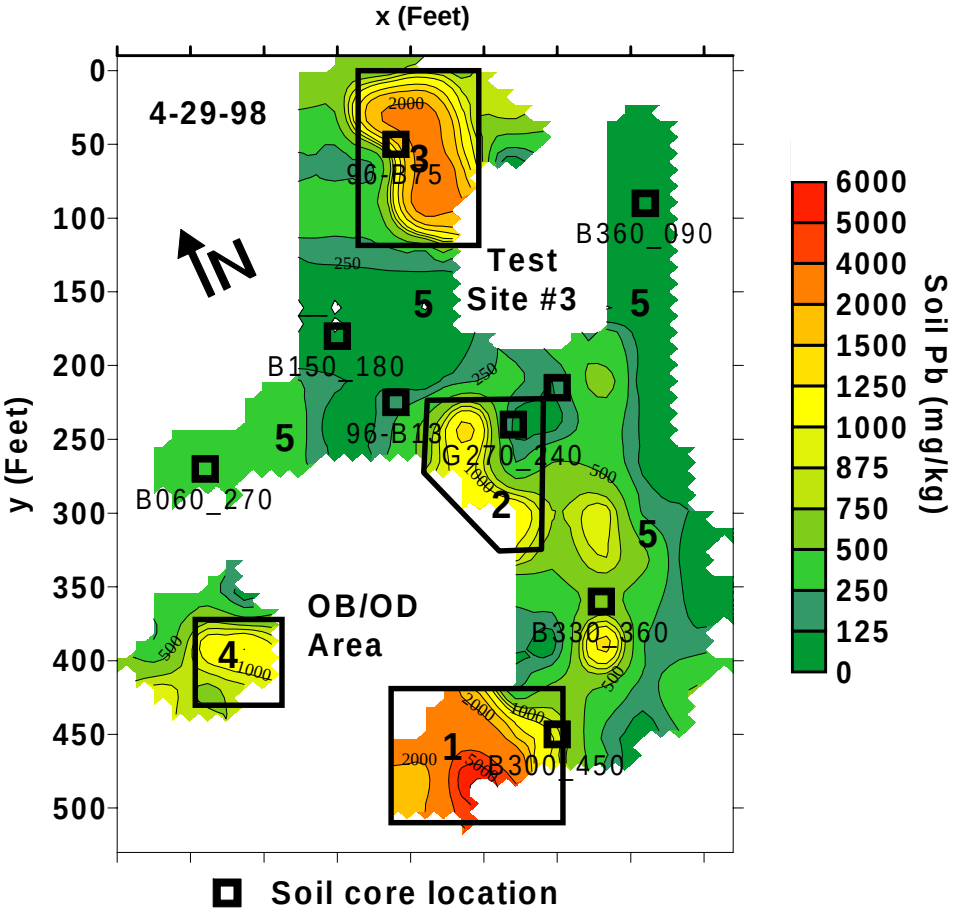

Figure 1. Distribution of Surface Soil Lead Concentrations at Treatment Areas 1-5 (modified from Phytotech, Inc., 1999).

surface soil lead concentrations greater than 1000 mg/kg and SPLP leachable lead greater than 0.015 mg/L. Area 5 (approximately 83% of the total treatment area, or 2 acres) had surface soil lead concentrations less than 1000 mg/kg and SPLP values greater than 0.015 mg/L. The soil lead concentrations in each of the five areas are shown in the contaminant profiles in Figure 1, and the lead soil concentration ranges in each area are presented in Table 2. Based on the sampling results, Areas 1 through 4 (highest concentrations) were treated using phytoextraction, and Area 5 (lower concentrations) was treated using phytostabilization.

Table 2. Ranges of Soil Lead in Areas 1 through 5 and Phytoremediation Technology Selected

Area[a]	Range of Soil Lead (mg/kg)	Technology Selected
1	500 – 5000	Phytoextraction
2	125 – 1250	Phytoextraction
3	500 – 2000	Phytoextraction
4	750 – 1000	Phytoextraction
5	6.5 – 7.5	Phytostabilization

a. Refer to Figure 1 for location of Areas 1 through 5.

Technology Description and System Design

Site preparation activities began in April 1998. Soils were fertilized with nitrogen, phosphorus, and potassium. Dolomite lime was also added to the soil to adjust the soil pH to within a range for optimal plant growth and metal uptake. The fertilizers and lime were tilled into the soil to a depth of 15 to 20 cm. Then the areas were mechanically seeded with Indian mustard (*Brassica juncea*). An overhead irrigation system was installed to provide adequate moisture for plant growth, and an irrigation gauge was used to monitor moisture.

Plant growth, potential plant pathogen and pest infestations, and overall crop development were periodically assessed. Supplemental foliar fertilizers were added through the irrigation system on an as needed basis. Plant and soil samples were collected at key growth stages to aid in crop diagnostic and development evaluations. (Phytotech, Inc., 1999)

The phytoextraction technology was implemented at Areas 1-4 to remove soil lead in areas having greater than 1000 mg/kg. The hyperaccumulating species Indian mustard and sunflower were

used in conjunction with two chemical additions. The first chemical additive was a soil-applied amendment formulation designed to increase the bioavailability of the lead. The second chemical additive way site-specific foliar compounds designed to enhance removal of lead from the soil and enhance uptake and translocation into harvestable above-ground plant tissue. Three crops were planted: one crop of Indian mustard, one crop of sunflower, and one crop that was a mixture of the two. The chronology of phytoextraction treatment of Areas 1-4 is presented in Table 3.

Table 3. Chronology of Phytoremediation in Areas 1 through 5

Treatment Crop	Time Period	Activity	
		Areas 1 – 4 (Phytoextraction)	**Area 5 (Phytostabilization)**
1	End-April 1998	• Indian mustard (*Brassica juncea*) planted	• Indian mustard *(Brassica juncea)* planted
	June 1998	• Treated with plant and soil amendments to enhance solubility and uptake	• Treated with foliar amendments only to enhance uptake
	Mid-June 1998	• Crop harvested	• Crop harvested
2	End-June 1998	• Sunflower (*Helianthus annus*) planted	• Stabilizing amendments added • Sunflower (*Helianthus annus*) planted
	July 1998	• Treated with plant and soil amendments to enhance solubility and uptake	• Treated with foliar amendments only to enhance uptake
	End-July 1998	• Crop harvested	• Crop harvested
3	August 1998	• Mixture of Indian mustard (*Brassica juncea*) and Sunflower (*Helianthus annus*) planted	• Stabilizing amendments added • Mixture of Indian mustard (*Brassica juncea*) and Sunflower (*Helianthus annus*) planted
	September 1998	• Treated with amendments for solubility and uptake	• Treated with foliar amendments only
	October 1998	• Crop harvested	• Crop harvested

Source: Phytotech, Inc., 1999

The phytostabilization technology was implemented at Area 5 in areas that were below 1000 mg/kg total lead and over 0.015 mg/L leachable lead. Amendment application was designed to enhance

plant biomass production, soil lead uptake, and stabilization of existing leachable (SPLP) soil lead without enhancing the solubility of additional soil lead. The phytostabilization was not designed to result in any further significant reduction in the total soil lead concentration. The chronology of phytostabilization treatment of Area 5 is presented in Table 3.

Technology Performance

Plant growth for each of the three 1998 treatment crops was generally good. Certain areas within the treatment area remained excessively wet throughout the growing season; these areas exhibited poor plant growth and reduced biomass yields. Some of the sunflowers from treatment crop 2 required replanting.

During phytoextraction total soil lead concentrations in the surface soils in Areas 1-4 decreased from an average of 635 mg/kg (April 1998) to 478 mg/kg (October 1998). The phytoextraction program has reduced the highest total lead concentrations so that no samples in excess of 4000 mg/kg were found. Before phytoremediation, 7% of the total treatment area had soil lead concentrations above 2000 mg/kg. After treatment, only 2% of the area had concentrations above 2000 mg/kg. The percentage of the total treatment area having concentrations greater than 1000 mg/kg was reduced from 17% to 16%. The contaminant profiles in Figure 2 show the distribution of surface lead contamination before and after treatment. A comparison of the April (before treatment) and October (after treatment) 1998 contaminant profiles in Figure 2 shows that the highest concentrations in Areas 1-4 have been reduced.

Lead uptake ranged from a low of 342 mg/kg (dry weight) in the Indian mustard in treatment crop 1 to 3252 mg/kg in the Indian mustard in treatment crop 3. Average lead uptake measured in the sunflower plant material and Indian mustard were similar, having average lead concentrations from all crops of approximately 1000 mg/kg (dry weight).

During phytostabilization, the average reduction in SPLP lead concentration in Area 5 was 0.95 mg/L.

Technology Cost

No cost information was provided by Edenspace Systems Corp. (formerly known as Phytotech, Inc.).

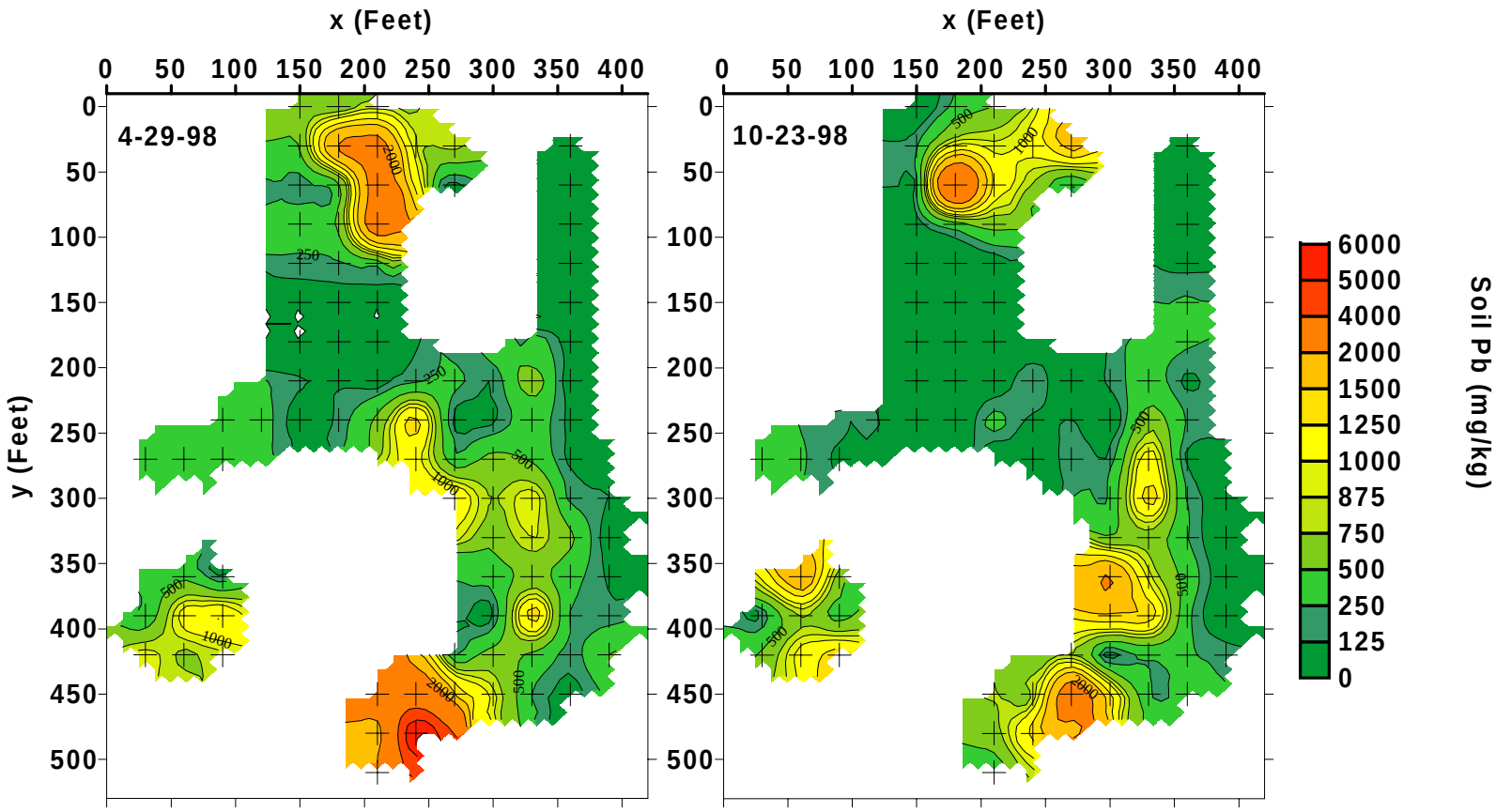

Figure 2. Distribution of Surface Soil Lead Concentrations Before (4-29-98) and After (10-23-98) Phytoremediation (modified from Phytotech, Inc., 1999)

Summary of Observations and Lessons Learned

After the 1998 treatment, the following observations and recommendations were noted:

- The ongoing phytoextraction program continued to reduce site-wide average total lead concentrations at a rate of approximately 150 – 160 mg/kg per year (Phytotech, Inc., 1999).

- Upon reviewing the results of the 1998 phytoremediation season, it was suggested that the areas having total lead concentrations less than 1000 mg/kg be treated again using phytostabilization, and areas having concentrations greater than 1000 mg/kg be treated again using phytoextraction. Because the greatest total lead concentration reductions occurred in the areas containing the greatest initial concentrations, phytoextraction is expected to significantly further reduce the area requiring additional phytoextraction treatment. (Phytotech, Inc., 1999)

- Field based soil survey techniques can be effectively used to determine remedial applications and validate treatment effectiveness. A field based XRF instrument was used to map surface lead concentrations, and the analyses correlated well (r=0.928) with laboratory based lead analyses.

- Planted systems are vulnerable to unpredictable climatic conditions. Re-planting and less than optimal yields of the sunflower crop were observed.

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